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MATERIALS HANDLING FOR LIVESTOCK FEEDING

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Efficient systems for handling materials, particularly livestock feeds, are becoming more and more essential in modern agricultural practice. This publication presents information from which various types of feed conveyors can be selected and designed, and also describes latest handling methods for various feeds used by livestock and poultry growers. Engineering formulae necessary in designing feed and conveyor systems, and actual examples of calculation procedures in system designing, are also included.

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MATERIALS HA

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The principles of materials handling are the same for farm operations as for industry. They include:

1. The elimination of unnecessary handling of materials. The system should be as simple as possible. (Store the material handy to the next operation. Let animals self-feed.)

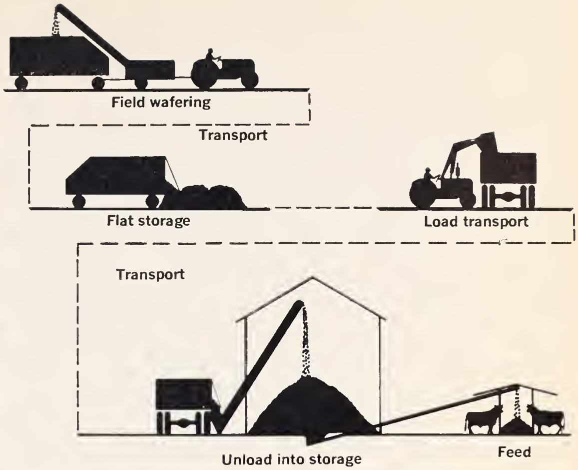
2. Making the flow of material more continuous by eliminating unnecessary storage points. (Mechanize unloading of storage, or improve flow characteristics of material to promote gravity flow.)

3. Handling large amounts of materials at a time. (Make each trip count; avoid small batches.)

4. The use of condensed free-flowing forms of materials. (Low-density materials are hardest to handle and are expensive to store.)

Materials to be handled in a feeding operation vary from free-flowing grains to low-density fibrous material, such as hay, and from water to sticky, viscous fluids, such as molasses. A knowledge of

Fig. 1. Three tons of baled hay on an 8′ x 8′ pallet. Once stacked this way subsequent moves can be made by machine.



The trend toward bulk handling. A schematic drawing of a hay wafer handling system (see figures 2 and 3, below).

LING FOR LIVESTOCK FEEDING

the handling characteristics of the materials to be used is very important in planning suitable equipment.

The Trend Toward Bulk Handling. Mechanization of feed preparation and livestock feeding usually is accompanied by a change to bulk handling. Large mechanized operations use sacked feeds only when volume does not warrant bulk handling. Grain, and most ground feeds, can be economically handled in bulk even in small mixing and feeding operations.

Hay is now the only major feedstuff handled piecemeal. Even baled hay is sometimes handled in bulk (fig. 1), and equipment is being developed to put this feed in smaller, highly compressed packages ("pellets" or "wafers") having improved handling characteristics. Ultimate success of hay pelleting in the field is largely dependent upon development of handling methods that will reduce labor and utilize the greater density and improved flow characteristics of pelleted

Fig. 2. Loading a transport truck with wafered hay.

Fig. 3. Self-feeding barn for wafered hay. Barn holds 500 tons of wafered hay which flows by gravity to feed bunks.

hay. Examples of current wafer handling, storage, and feeding are shown in figures 2 and 3.

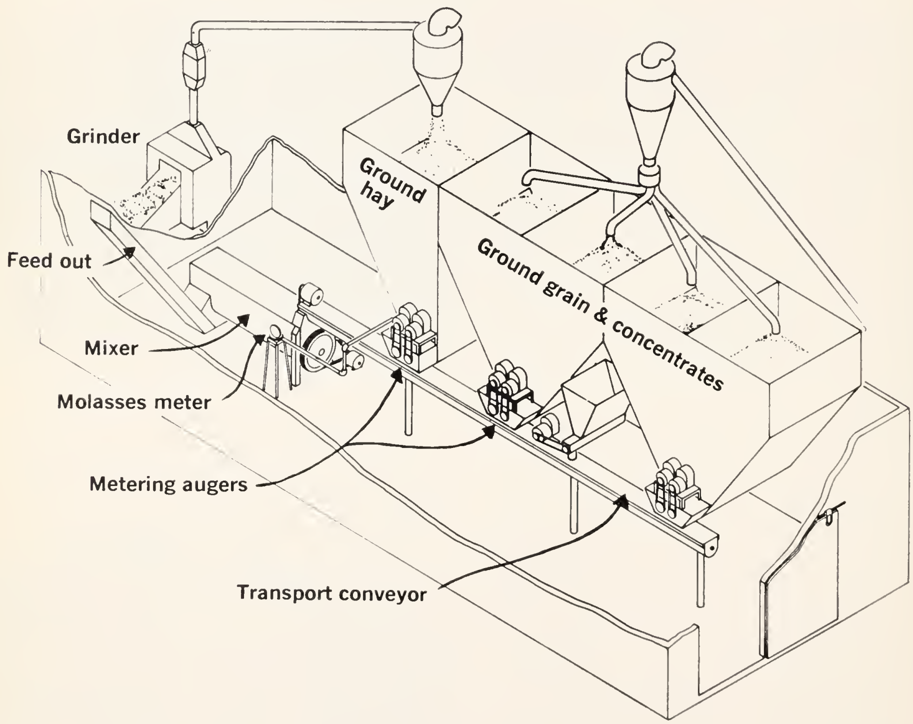
Processing Raw Materials into Feed: Percentage and Batch Mixing Mills. Feed mills vary from simple farm-sized operations to large feed lots and commercial plants. The basic operations are similar, regardless of size, but large mills are usually much more flexible and can justify complete mechanization and perhaps even some automation.

Feed mills are of two general types: percentage mix, and batch mix. In percentage mills, proportioning is accomplished by metering feed into a continuous-flow blender. The uniformity of the mix will depend on the accuracy of the volumetric metering devices and the ability of a single-pass mixer to mix thoroughly. Molasses may be added in the continuous-flow mixer. Two types of percentage mills are shown in figures 4 and 5.

In batch mixing plants, such as the one shown in figure 6, the various ingredients are weighed into a batch mixer and agitated for 1 to 5 minutes. The batch system usually provides a more accurately measured ration, because the various ingredients are weighed and the cycle of the recirculating mixer can be controlled. Over-mixing may cause separation of the ingredients. In either system, minor ingredients should be pre-mixed with other material to aid thorough blending in the main mixer.

Grinding Ingredients for Livestock Feeds. Hay and grain—the major ingredients in livestock feed—are usually

Fig. 4. Schematic view of percentage type of mixing plant with continuous mixer. Ingredients are metered into the transport conveyor at a predetermined rate. Molasses is added in the mixer.



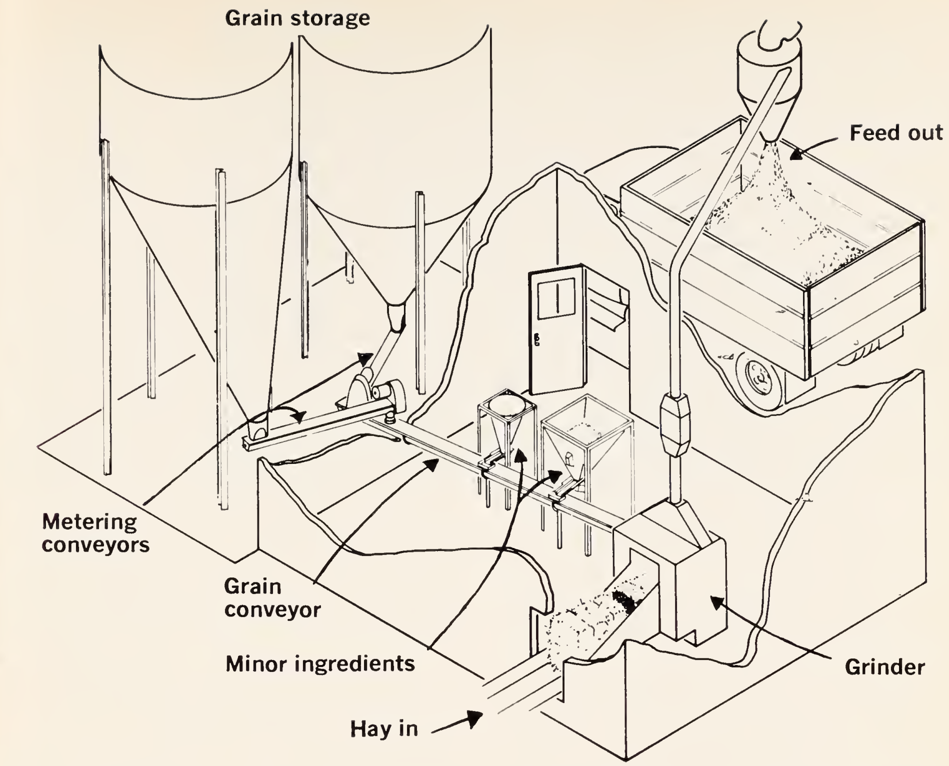
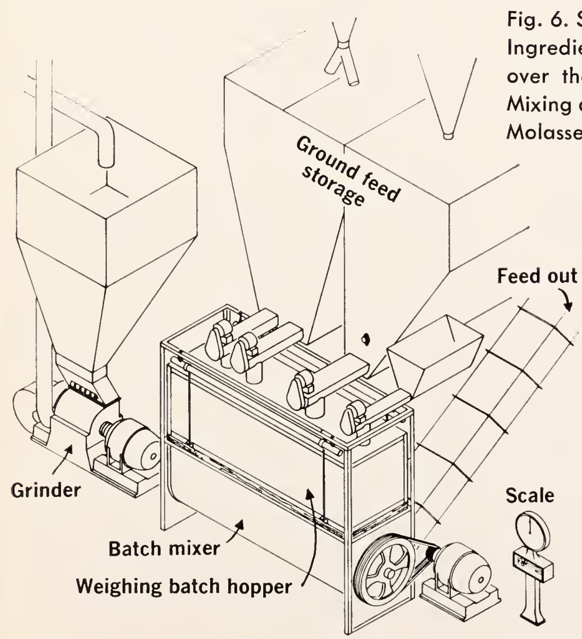


Fig. 5. Schematic of simplified percentage mixing plant using grinder as a mixer. Proportioning of ingredients is controlled by varying speed of hay and grain conveyors. Molasses may be added in a separate mixer.

Fig. 6. Schematic view of a batch mixing plant. Ingredients are weighed into dust-tight hopper over the mixer, then dumped into the mixer. Mixing and weighing may occur simultaneously. Molasses usually is added in a separate mixer.



ground or rolled before they are blended. Some residue feeds, such as almond hulls and corn cobs, also require grinding.

Hay and other coarse, fibrous materials are ground almost exclusively with a hammermill (for baled hay, a bale breaker or shredder must be placed ahead of the grinder). When grinding hay or forage with a hammermill, its capacity will decrease with (1) an increase in the moisture content of the hay and (2) a reduction in ground particle size. In grinding dry baled alfalfa for cattle the hammermill power requirements will generally range from 20 to 30 horsepower-hours per ton.

The three main types of mills in use for grinding grains in California are (1) hammermill, (2) steam roller, and (3) crimper. The burr mill is used to a limited extent. The principal considerations in selecting a mill for grain would appear to be the type of grind it produces and the cost. The table below shows a standard sieve analysis for barley samples processed by the three different machines. Steam rolling provides coarser feed than the other machines.

PARTICLE SIZE OF BARLEY
GROUND BY THREE TYPES OF MILLS

Particle Size	STEAM ROLLER per cent of sample	HAMMERMILL 3/8" SCREEN per cent of sample	CRIMPER per cent of sample
Coarse (3/64" or larger)	98.0	27.5	41.0
Medium (.011" to 3/64")	1.6	69.5	55.0
Fine (less than .011")	0.4	3.0	4.0

The cost of grinding is based primarily on the first cost of the machine per ton per hour capacity, and its power consumption per ton. The following table gives a general comparison of these two items for grinding grain with a hammermill, steam roller, or crimper.

	Capacity, hp.—hr. per ton	First cost, dollars per ton per hr. capacity*
Hammermill	8–10	350– 600
Steam roller	5– 8	1200–1700
Crimper	1.5–2.0	300– 350

* Includes the price of electric motor plus an installation charge of 20% of the cost of the machine and the motor. For the steam roller it includes the cost of the steam boiler.

Pelleting. Pelleting equipment can be added to either a batch-mix or continuous-mix operation. The mixed feed is delivered to a surge bin above the pellet mill. Molasses may be added in the pellet-mill mixing chamber. The pellets pass through a cooler to bulk storage or the delivery truck. Optimum pellet quality, with a minimum of fines produced, requires fine grinding, uniform mixing of ingredients, and an ample supply of dry steam.

APPROXIMATE COSTS OF PELLETING
FEEDS IN ADDITION TO NORMAL
PLANT COSTS

Investment Cost	$20,000 to $30,000
Mixed feed—pelleting only	$2 to $3 per ton
Grinding and pelleting roughage	$5 to $9 per ton

Bin Design. Bulk handling requires storage bins to provide a ready supply of material for feed-mill operation. Bins are used for long-term storage of raw materials and also for temporary storage of processed ingredients or mixed feeds. Storage bins should be designed to maintain the material in a suspended condition, permitting spontaneous flow when the bin outlet is opened. Two such bins are shown in figure 7. Note the difference in slope of the sides. The bin on the right has a 45-degree slope, which is for free-flowing material such as clean barley. The steeper slope (60 degrees) on the other bin is needed for coarsely ground feed or trashy grain. The offset feature provides a near-vertical wall to relieve the tendency of the material to bridge. The offset hopper design may also be used in rectangular bins.

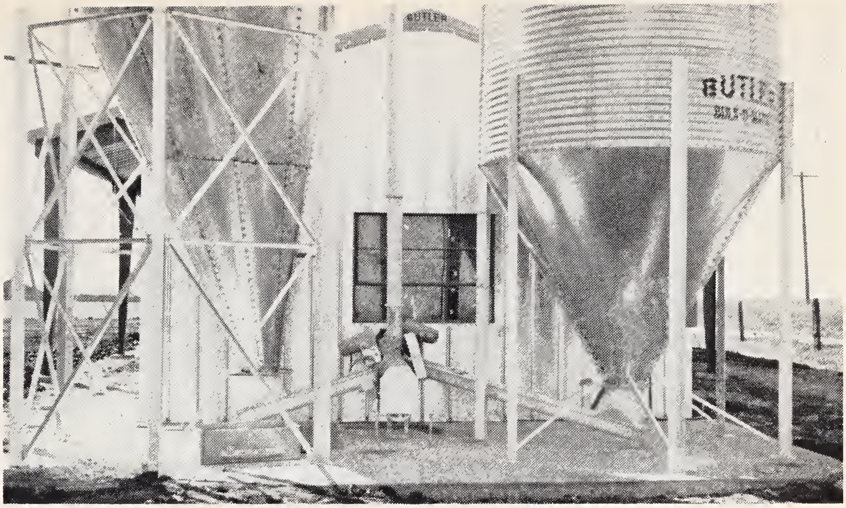


Fig. 7. Two designs of gravity flow, hopper-bottom bins.

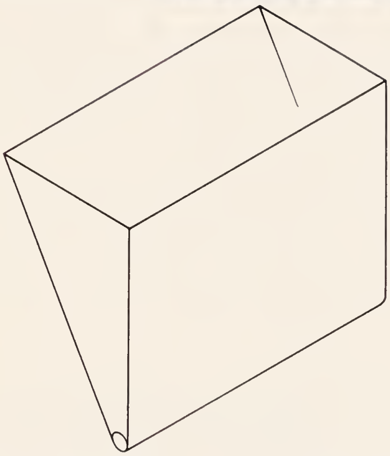
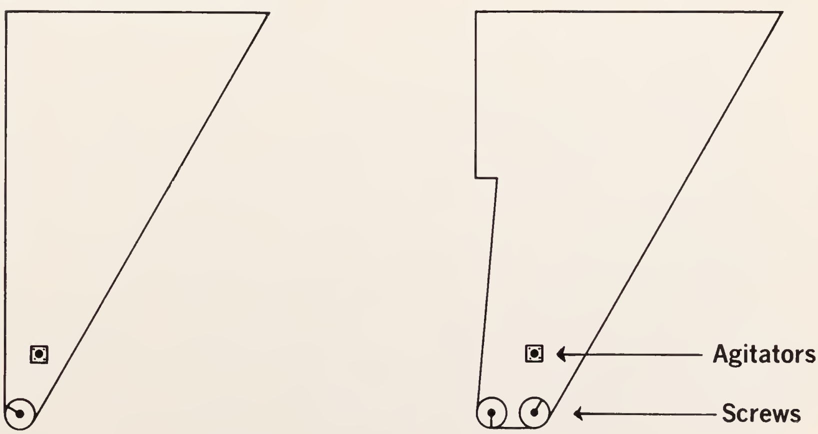


Fig. 8. Mechanically unloaded bin for poor-flowing ground materials. One side and two ends vertical, one side sloping 60 degrees.

Storage of material in a bin provides an opportunity for settling, and settling often changes the flow characteristics of the material. Mechanical unloading provides improved assurance of uniform flow. Figure 8 shows a type of bin commonly used for many ground materials. A screw conveyor is used for unloading. This design is adequate for any material that does not bridge easily. Designs with mechanical aids to overcome bridging are shown in figure 9.

Ground or chopped hay presents the most serious problem in bin design. A full-moving-bottom bin should be provided to ensure positive flow of material. Figure 10 shows a vertical-sided bin with a full-moving-bottom of the types shown

Fig. 9. End view of bins showing methods of unloading poor-flowing materials. Agitator is used above conveyor to eliminate bridging.



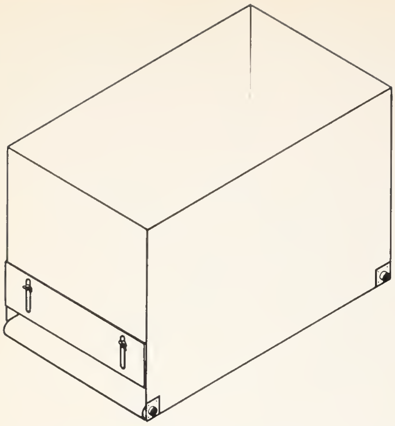


Fig. 10. Full-moving bottom bin for problem materials. Bin walls should be vertical or near-vertical.

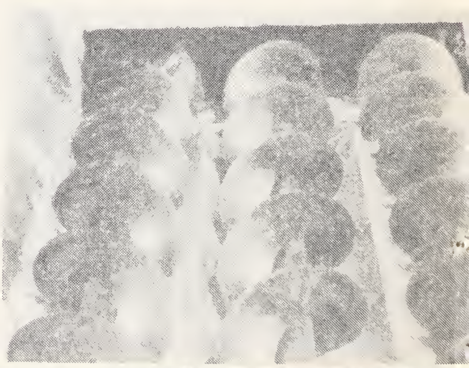
in figure 11. Multiple screw installations (fig. 11) are widely used with vertical- or near-vertical-sided bins for ground hay.

Feeding Livestock Mechanically. Mechanized feeding is practiced to some degree in nearly every livestock enterprise. Many methods have been devised for use on small or medium-size operations, but portable power-unloading wagons have become standard equipment for feeding in most large beef feed lots and on many dairies in California. Electric-powered conveyors are limited to small operations and to dairies. Practical limits to length of individual units control the number of animals that can be fed by conveyor from a central loading point. Most existing feed lots are more adaptable to wagon or truck feeding than to conveyor feeding.

Mechanical unloading wagons or trucks are used to handle many different types of feed. On a beef feed lot, one wagon may at different times feed chopped green alfalfa, silage, mixed dry feed, grain, beet pulp, or dry chopped hay. The operator can adjust the rate of feeding either by speed control built into the wagon power unit or by varying the ground speed. Front-unloading wagons provide the best view of feed discharge. Power for unloading is provided by power takeoff or by a gasoline engine mounted on the wagon. Numerous unloading wagons and trucks are produced commercially (fig. 12). They can also be obtained mounted on scales to facilitate controlling the amount of feed delivered.

Most feed wagons can be loaded with mixed or unmixed feed rations. The preferred arrangement is to load with a premixed ration from a mixer or bin. In the second system, uniform layers of each

Fig. 11. Two types of conveyors used in full-moving bottom bins.



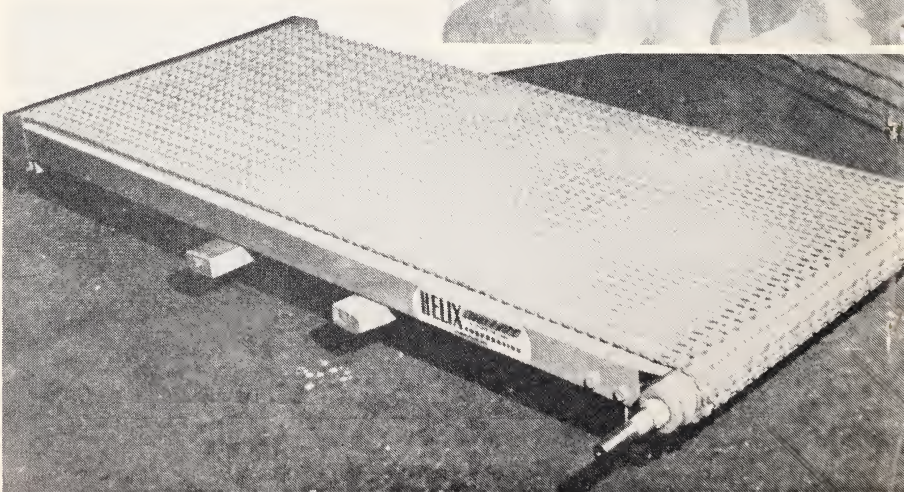


Fig. 12. One feed wagon can handle several thousand head of cattle and can feed chopped hay, silage, or mixed feed.

Fig. 13. This feeder, 400 ft. long, feeds 500 cattle in 20 minutes. A continuous-feed mixer deposits feed on the 30-inch-wide conveyor, which is operated 3 or 4 times a day with a 3-hp. motor.

feed ingredient are spread in the wagon so that the augers above the cross conveyor do the mixing by cutting across the layers. This system requires more care in loading and results in a less uniform ration than with pre-mixed feed, but it does simplify and reduce the cost of the feed-processing plant.

Several types of mechanical conveyors may be used to feed mixed rations. One system consists of a long flight conveyor or belt onto which the mixed feed is metered from a continuous mixer or supply bin. This conveyor carries the feed along a feed trough and the animals eat from both sides of the conveyor (fig. 13).

A traveling feed cart that moves along or above a feed trough, metering out feed as it travels, can also be used for mixed feed (fig. 14). The feed cart is similar in principle to the mechanical unloading wagon, but operates on rails above or beside the feed bunk. It deposits feed at a constant rate, governed by the rate of travel of the cart.

A bottom-carrying flight conveyor or

Fig. 14. Travelling feed cart is filled from overhead hopper-bottom bin (left), and deposits feed in the bunk at the preset rate, controlled by the speed of the cart (right).

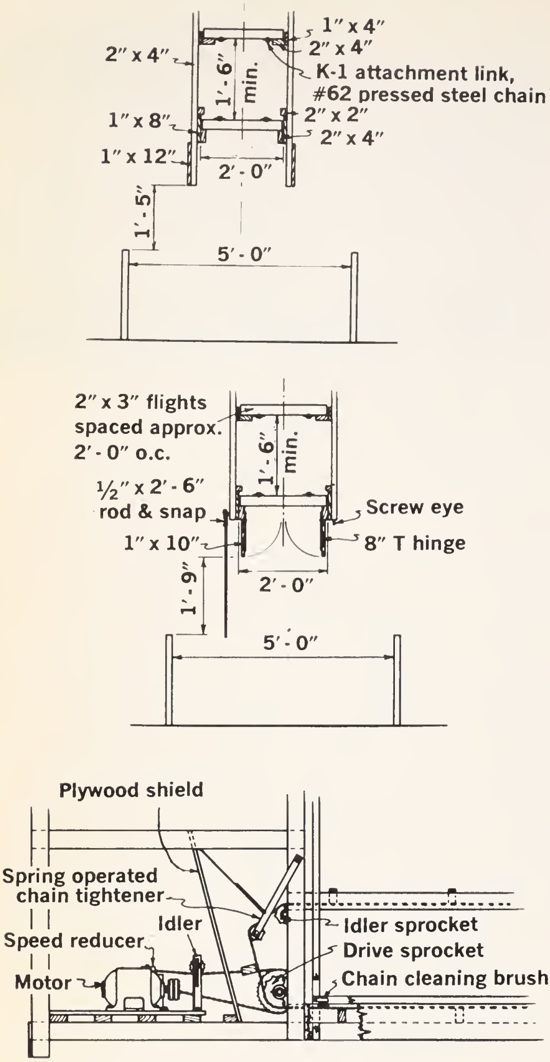


Fig. 15. Chopped hay feeder showing cross-section with stationary sides (top), hinged floor (center), and drive unit. Insert free end of rod in screw eye to hold up bottom of conveyor.

screw suspended above a feed bunk may be used where free-access feeding of chopped hay or silage is desired (fig. 15). The bottomless conveyor is centered over the feeder and fills first at one end. Then, as feed builds up to form a bottom in the conveyor, the feed is carried farther along until the entire feed bunk is filled. With forage, the bottomless conveyor should not be longer than 50 ft. Otherwise, friction between the forage carried by the conveyor and that in the bin below becomes too great for smooth operation. Longer conveyors should be provided with a partial floor, or with a hinged floor at the inlet end which can be dropped after the far end of the feeder has been filled. The width of the feeder and the height of the conveyor above the feeder will control the amount of feed deposited per unit of length.

Hand-pushed movable feed bunks on rails (fig. 16) have been used to carry silage or mixed feed to the feed lot. A train of feed bunks, mounted on flanged wheels, is pushed along the rails into the feed yard. Cows eat directly from the feeders, which are made of 2-in. lumber for weight and strength. The operation requires a back-track equal in length to the train of feeders. Figure 17 shows an electric drive, operating on the rack-and-pinion principle, that will move the train in either direction at a pre-determined speed, permitting uniform loading from a continuous feed supply.

Mechanizing the feeding of concentrates during milking saves time and many steps (fig. 18). The mechanical systems now in use provide a ready supply of feed that can be released at the head of each cow in a metered amount by

Fig. 16. Wheeled feed bunks, 5 ft. wide, are hand pushed between silos. Silage is uniformly deposited in feed bunks, which are moved into the feed yard.

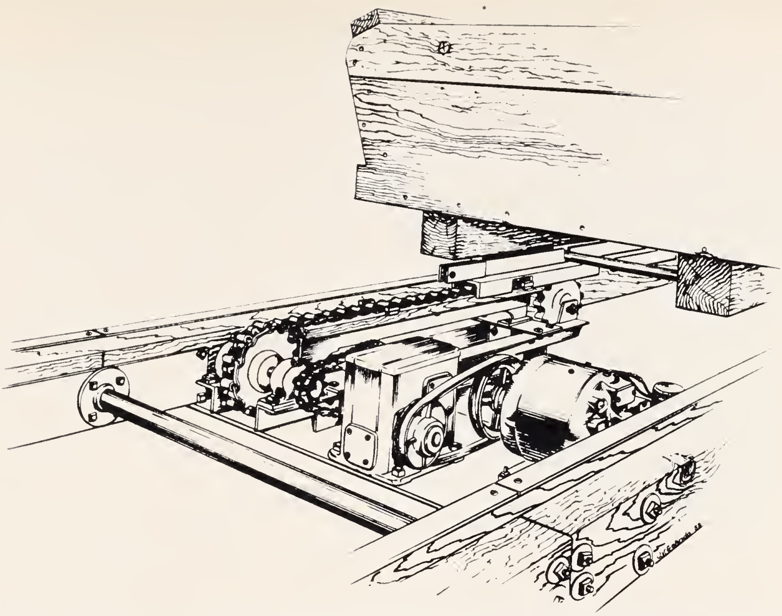
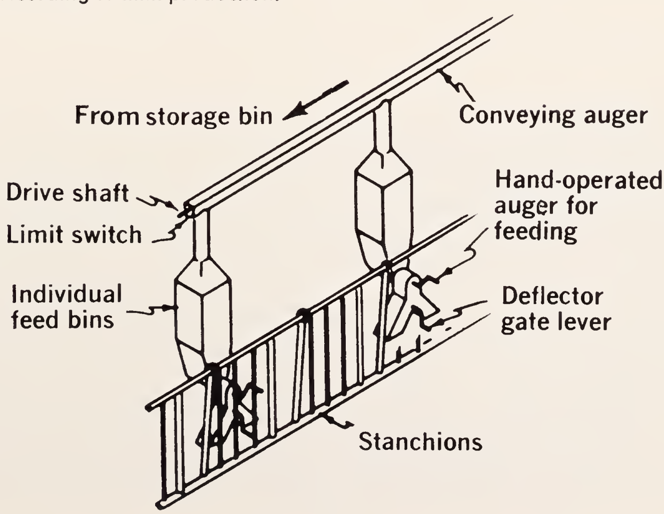


Fig. 17. Electric drive unit for wheeled feed bunks. One-half-hp. motor operates rack-and-pinion type drive in either direction.

turning or pulling a lever from the milking side of the stanchion. The feed is carried to the individual hoppers over the stanchions, either by gravity from a rooftop bulk bin or by a dust-tight overhead auger or drag conveyor. With bulk delivery of feed to the ranch, handling may be reduced to a minimum.

Fig. 18. Mechanical system for delivering concentrates to each stanchion in milking parlor. Overhead screw fills individual hoppers. One pound of feed drops into the feeder with each turn of the crank. This system can be adapted to any type milking parlor, and feed can be delivered automatically according to milk production.



SILAGE HANDLING

Fig. 19.

There are three basic systems used in California for handling and feeding silage, and they are related to the type of silo used as described below:

Trench or Bunker Silo. Mechanical loading of a feed wagon, combined with bunk or manger feeding. Figure 19 shows one type of mechanical loader; tractor-mounted skip loaders are also used.

Upright silo. Mechanical silo unloader combined with mechanical conveyors which distribute silage to feed bunks or mangers. Figure 20 shows screw conveyor used to feed silage. This system is similar to the chopped-hay feeder shown on page 10, but is more often used for daily feeding.

Bunker Silo, Self-feeding. Animals feed directly from silo through movable mangers (fig. 21). The mangers are moved ahead as silage is consumed.

Fig. 20.

Fig. 21.

CONVEYOR DESIGN INFORMATION

Types of Conveyors and When to Use Them

Type of Conveyor	*Type of Material*	*Capacity*	*Horsepower Requirement*	*Cost*	*Advantages*	*Disadvantages*
Chain	Most feeds, grains and farm products	Medium	Medium	Low to medium	1. Inexpensive 2. Multiple use	1. Noisy 2. Heavy wear factor
Belt	Grain, packaged units	High	Low	High	1. Can be used for long distances 2. Low power requirement	1. Limited in angle of elevation 2. Expensive
Screw	Ground, granular, or chopped	Medium	Low to medium	Medium	1. Can be used as mixer or for uniform flow feeder 2. Good for unloading bulk storage	1. Size of material limited 2. Single sections limited in length
Bucket	Ground, granular, or lumpy	Medium	Low	Medium to high	1. Efficient 2. Minimum space requirement 3. High capacity for vertical lift	1. Limited speed range 2. Should have automatic brake
Pneumatic	Grain, ground feed, chopped forage	Variable	High	Low to medium	1. Low first cost 2. Low maintenance 3. Flexibility of installation	1. High power requirement 2. Creates dust, requires separation equipment 3. Conditions of operation vary with type of material 4. Excessive manpower may be needed to clear plugged pipes.

BELT CONVEYORS

BELT SELECTION

Consider:

1. Width—for ample capacity.

2. Flexibility—for size of pulleys used.

3. Strength—for load and tension.

4. Surface — wear and corrosion resistance.

Suitable belting for farm use: stitched canvas, solid-woven, balata, rubber. Canvas and woven belts should be waterproof.

PULLEY SELECTION

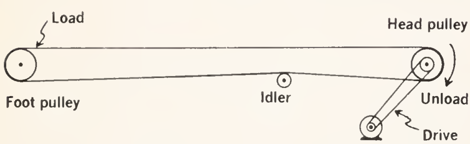


Fig. 22.

Size. Consider:

1. Contact surface for belt on driven pulley.

2. Flexibility of belt.

3. Speed of belt.

Belt Tension. Allow for change in belt length with automatic weighted or spring-loaded tighteners, either on foot pulley or an idler pulley.

LOADING

Free-flowing material. Gravity flow from hopper with gate valve or level control.

Other materials. Manually or by flight, screw, or other conveyors.

Surcharge — comparable to load carried by flat belt

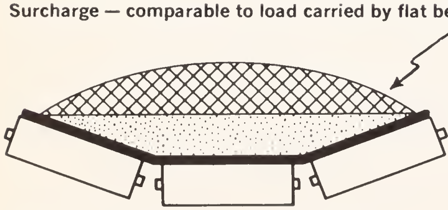


Fig. 23. Cross section of loaded belt.

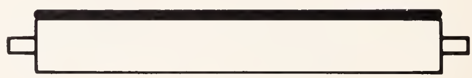
SUPPORTING IDLERS OR TABLE

For flat or troughed belts carrying heavy loads for long distances.

Fig. 24.

Troughed belt

For granular or lumpy materials. Unloaded from end or by tripper.



Flat roller

For packaged materials or return for troughed belt. May be used with side board for bulky material. Unloading at any point with angle scraper, or by tipping belt.

Sliding table

Same as above, but limited to short runs or light loads. Higher friction and wear on belt—may be minimized with smooth wood or sheet metal table.

UNLOADING

End delivery. Allow material to drop off as belt reverses direction at head pulley.

Diagonal scraper. For flat belts. Causes some extra friction and wear.

Tipping belt. For flat belts. Movable shim under one side of belt effects unloading over considerable distance. Useful only on long belts because of tendency to stretch one side of belt.

Tripper. Usually used on troughed belt. Movable S-shaped pulley arrangement unloads at top onto chute or cross belt. Expensive.

BELT CONVEYOR DESIGN

It is recommended that installation of heavy-duty belt conveyors be designed and supervised by a competent engineer. The following design information will serve as a guide for light duty and most farm installations.

CAPACITY OF BELT CONVEYORS—UNIFORM LOADING—100 FPM (FEET PER MINUTE)

Belt width	*Troughed belts*		*Flat belt*	*Maximum speed*	
	35 lb./cu. ft. material	50 lb./cu. ft. material	50 lb./cu. ft. material	Fine grind	Grain
inches	tons/hr.	tons/hr.	tons/hr.	fpm	fpm
12	8.1	11.5	5.7	300	350
14	11.8	15.8	7.1	300	400
16	14.7	21.0	9.5	300	450
18	18.1	25.9	11.6	400	450
20	23.4	33.4	15.0	400	500
24	34.3	49.0	22.0	500	600
30	55.2	78.8	35.5	550	700
36	77.3	110.2	50.0	600	800
48	153.0	219.0	99.0	600	800
60	252.0	360.0	162.0	600	800

POWER TO DRIVE CONVEYOR

This must be calculated in three parts: (The following formulae are for troughed belts running on anti-friction idlers.)

1. Hp. to drive empty conveyor $= \dfrac{S(.015 + .0001\ WL)}{100}$

2. Hp. to convey material horizontally $= \dfrac{\text{capacity}\ (0.48 + 0.00302\ L)}{100}$

3. Hp. to lift material $= \dfrac{\text{lift} \times 1.015 \times \text{capacity}}{1000}$

where W = width of belt in inches
L = length of conveyor in feet
S = belt speed in feet per minute

Capacity in tons per hour
Lift in feet

Formula **1** is approximate, but is accurate for belts up to 36 inches wide; for wider belts, add 20%.

4. Total hp. = **1** + **2** + **3**

Note: For sliding belt conveyors friction is increased. Substitute formulae **1** and **2** as follows:

1. Hp. = $\dfrac{S(.015\ W + 0.001\ WL)}{100}$

2. Hp. = $\dfrac{\text{Capacity}\ (0.48 + 0.0302\ L)}{100}$

BUCKET ELEVATORS

Where Used. Bucket elevators are used to lift ground, granular, or lumpy materials vertically or through a steep incline. They are quite efficient, having medium capacity with low power requirement. They are relatively easy to construct and require very little floor space. They are widely used in farm-size feed grinding and mixing plants.

Types Used. The centrifugal discharge type is the simplest and least expensive and is readily adaptable to

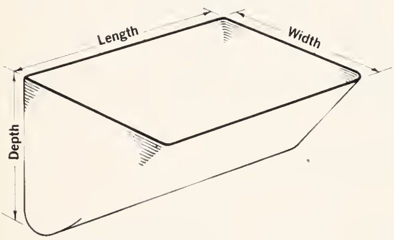


Fig. 25. Typical bucket.

materials used in livestock feeding. The buckets are evenly spaced and bolted on a continuous chain or belt which operates around a head wheel and a foot wheel. Material is picked up by the digging action of the buckets as they pass around the foot wheel. Proper speed, diameter of the head wheel, and position of the discharge are important for clean unloading.

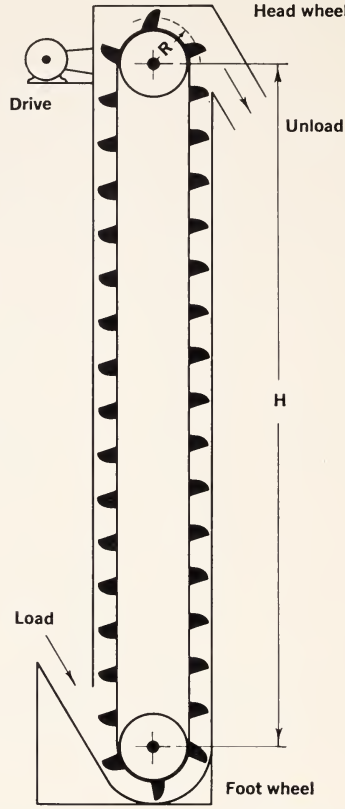


Fig. 26. Centrifugal discharge bucket elevator.

Chain or Belt? Either chain or belt is satisfactory for most farm elevators because of the nature of the material handled. Belt elevators may be operated at

Belt and Bucket Elevators

Capacity	*Buckets*		*Head shaft*		*Foot pulley*	*Belt*		
tons/hr. 45 lb./cu. ft. material	Size length × width	Spacing*	Pulley diam.	Speed† rpm	Diameter	Width	Ply	Speed fpm
4	4″ × 2¾″	9″	12″	70	12″	5″	3	220
7.5	5″ × 3½	11″	16″	61	15″	6″	3	255
11	6″ × 4″	12½″	20″	55	18″	7″	3	285
17	7″ × 4½″	15″	24″	50	22″	8″	3	315
25	8″ × 5″	16″	30″	45	24″	9″	3	355
40	10″ × 6″	18″	36″	41	24″	11″	4	390

* 3 times projected width.

† For chain, use 77% of capacity and speed.

higher speeds than chain and hence have greater capacity. On the other hand, chain provides positive drive and alignment. A single chain, either detachable link or combination (depending on the load), or 32-oz. belting, is normally used for farm elevators. Buckets are available in several sizes and forms. The most common form is shown here. Bucket spacing is 2 to 3 times the projected width of the bucket.

DESIGN OF ELEVATORS

Capacity. Determine capacity requirement of elevator. The table below indicates the amount of material carried by typical buckets.

CENTRIFUGAL DISCHARGE BUCKETS

Size	*Capacity*	
Length × width	Cu. ft.	45 lb./cu. ft. ft. material
inches		
4 × 2¾	0.01	0.45
5 × 3½	0.02	0.9
6 × 4	0.03	1.35
7 × 4½	0.05	2.25
8 × 5	0.07	3.15
10 × 6	0.12	5.4

Special buckets, 11 to 20 inches long, are available for ear corn.

Horsepower Required.

$$\text{Theoretical horsepower} = \frac{QH}{33{,}000}$$

where Q = amount of material handled, in lbs. per minute, and

Q = belt speed (fpm) × no. buckets per foot × capacity of bucket (lbs.)

H = lift in feet.

Head-wheel Radius and RPM Relationship.

For most satisfactory discharge conditions:

$$N = \frac{54.19}{\sqrt{R}}$$

where N = rpm of head wheel

R = effective head wheel radius in feet.

General. Where possible, the elevator should be driven through the head shaft, which is mounted on fixed bearings. The foot shaft is mounted on takeup bearings to provide adjustment for chain or belt wear. If for any reason it is necessary to use a fixed foot shaft, it should then be connected to the drive and the head shaft should be adjustable. The housing should be strong and well braced to withstand the tension between the head and foot shafts and the load on the elevator. An automatic brake is desirable to keep the unit from running backward in case of power failure.

TABLE 1. SELECTION CHART FOR COMMON CHAINS

Size	Type of chain	Links in 10 ft.	Weight per ft. (lbs.)	Working load, (lbs.)	Approximate cost per ft. ($)
No. 55	Detachable link—Cast	74	0.7	385	0.56
No. 62	Detachable link—Cast	73	1.04	535	0.77
No. 77	Detachable link—Cast	52	1.45	600	0.90
No. 55	Detachable link—Pressed steel	74	0.6	465	0.34
No. 62	Detachable link—Pressed steel	73	0.86	700	0.46
No. 955	Pintle—Riveted Malleable	74	1.9	1060	1.63
No. 962	Pintle—Riveted Malleable	73	2.5	1500	2.12
No. 977	Pintle—Riveted Malleable	52	2.0	1400	1.69
No. 55	Combination—Malleable	74	2.0	1100	1.68
No. 77	Combination—Malleable	52	2.2	1400	1.77

CHAIN CONVEYORS

TYPES OF CHAIN CONVEYORS

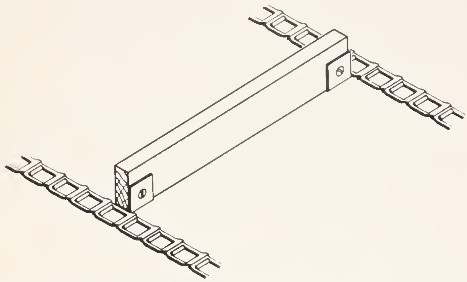


Fig. 27. Double chain conveyor. Most common type; variety of uses; chains may be at ends of cross flights.

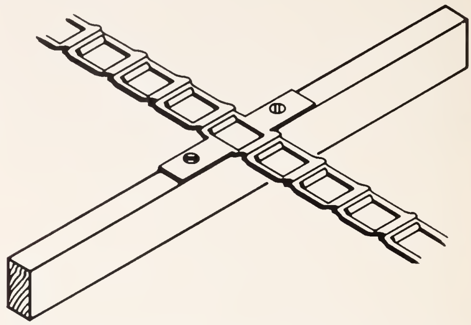


Fig. 28. Single chain conveyor. Can be used where material will not foul head sprocket; usually low speed.

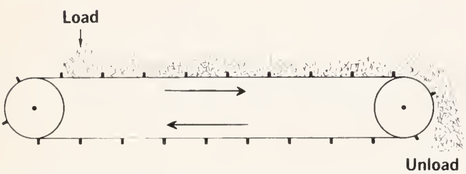


Fig. 29. Top-carrying conveyors unload at the head end.

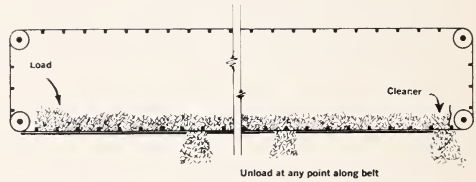


Fig. 30. Botton-carrying conveyors can be unloaded at any point along conveyor. Must be loaded from side.

Types of Chain	*Where Used*	*Example*
Malleable detachable Steel detachable	Light, intermittent use	Portable grain elevator
Pintle chain	Medium duty	Processing equipment
Roller chain	For rolling contact, less friction—free of abrasive material	Baled hay drag
Combination chain	Heavy duty—combines better qualities of other types	Mixed-feed conveyor Hay drag

CONVEYOR DESIGN

Total Pull on Chains. To determine number and size of chains, calculate the total pull on the chains.

For Horizontal Conveyor:

Total pull on chains = L (WF + 2wf)

where L = Length of conveyor, in feet

W = Weight of material handled (per foot of length), in pounds

w = Weight of moving conveyor parts (chains and flights) per foot of one run, in pounds

F = Coefficient of friction of material on trough (table 2, page 19)

f = Coefficient of friction of chain on runway (table 3, p. 19).

For Inclined Conveyor: Increase value of L by 2.5 times the vertical rise in feet.

TABLE 2. COEFFICIENT FRICTION (F) OF MATERIAL ON TROUGH

Material to be conveyed	Trough	Coefficient of friction (F)
Chopped dry hay or straw	Metal	0.30–0.35
Grain	Rough board	0.30–0.45
Grain	Smooth board	0.30–0.35
Grain	Metal	0.35–0.45
Coal	Metal	0.60
Dry sand	Metal	0.60
Chopped grass or silage	Metal	0.70–0.80

Power Required (including friction and allowance for overloads):

$$\text{Horsepower} = \frac{1.4 \times \text{conveyor speed (fpm)} \times \text{total pull on chains}}{33{,}000}$$

Capacity of Conveyor: For horizontal conveyor, capacity (cu. ft. per min.) = 1.15 $\times$ area of cross section of conveyor (sq. ft.) $\times$ speed (ft. per min.).

For inclined conveyors, reduce capacity of horizontal unit by these factors:

Incline of conveyor	*Relative capacity*
20 degrees	0.77
30 degrees	0.55
40 degrees	0.33

General. Apply power at head or discharge end, if possible.

Flights. Height, length, and spacing will vary with material to be conveyed. For granular material, flight height should be 0.4 $\times$ flight length, spaced the length of the flight apart. Use lower flights for bales, sacks, or ear corn. Steel or hardwood flights are preferred.

Chain Selection. After calculating load, select chain from manufacturers' catalogs. Total pull is divided by number of chains to determine working load on each chain. Catalogs allow for suitable safety factor. See table 1 (p. 17) for comparison of representative types and sizes of chain.

Sprocket Size. For smooth operation, not fewer than 12 teeth. At slow speeds, 6 to 8 tooth sprockets are sometimes used if space is limited. Too few teeth causes jerky operation and excessive wear.

Conveyor Speed. Ranges from 75 ft. per minute for materials of large granular size to 125 fpm for small granular materials. Use larger flights in preference to higher speeds.

TABLE 3. COEFFICIENT FRICTION (f) OF CHAIN ON RUNWAY

Type of chain or flight	Type of runway	Coefficient of friction (f)
Steel	Steel	0.57
Cast iron	Mild steel	0.23
Metal	Hardwood	0.50–0.60
Malleable roller	Steel	0.35
Roller bushed chain	Steel	0.20
Oak	Oak (cross fibers)	0.32
Oak	Oak (parallel fibers)	0.48

SCREW CONVEYORS

TYPES OF SCREW

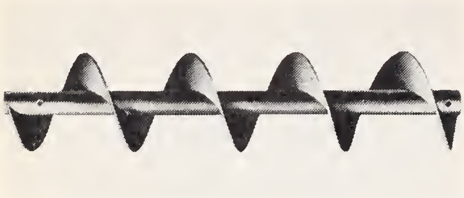


Fig. 31. Standard pitch for horizontal conveyor.

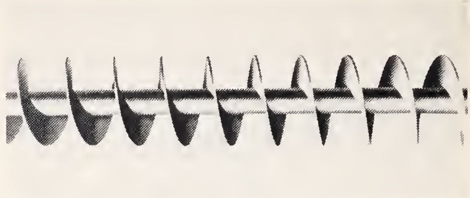


Fig. 32. ⅓ or ½ pitch for inclined or vertical conveyor and uniform feed conveyor.

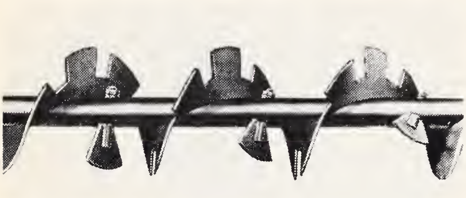


Fig. 33. Cut or paddle flight for mixing.

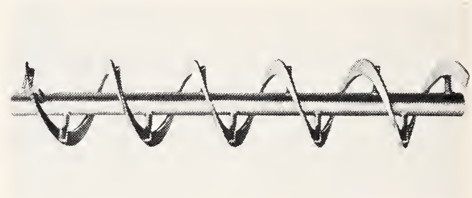


Fig. 34. Ribbon flight for sticky or viscous material (Figures 31–39 and 41–42 courtesy of Link Belt Co.)

CAPACITY OF SCREW CONVEYORS

Capacities and Speeds of Horizontal Screw Conveyors

Trough loading	*Screw diameter*	*Maximum lump size*	*Maximum recommended speed*	*Capacity-cu. ft./hr.*	
	inches	*inches*	*rpm*	*At maximum recommended speed*	*At 1 rpm*
	6	¾	165	375	2.27
	9	1½	150	1200	8.0
45 per cent	12	2	140	2700	19.3
	16	3	120	5600	46.6
	20	3½	105	9975	95.0
	4	¼	150	75	0.5
	6	¾	120	180	1.5
	9	1½	100	560	5.6
30 per cent	12	2	90	1200	13.3
	16	3	80	2510	31.4
	20	3½	70	4340	62.1
	4	¼	75	20	0.26
	6	¾	60	45	0.75
	9	1½	50	140	2.8
15 per cent	12	2	50	335	6.7
	16	3	45	705	15.7
	20	3½	40	1240	31.1

Note: Capacity decreases with angle of inclination, approximately 30% for 15° and 55% for 25°.

TYPES OF TROUGH

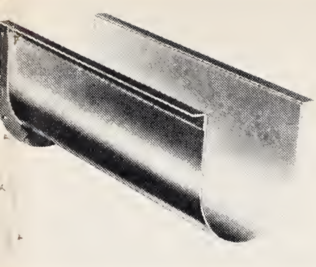


Fig. 35. U-shaped trough for horizontal conveyors; cover for dusty material optional.

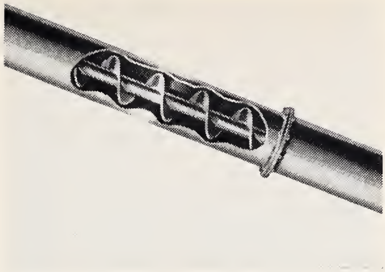


Fig. 36. Tube, for inclined or vertical conveyor.

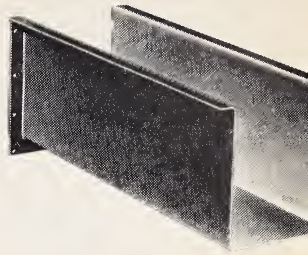
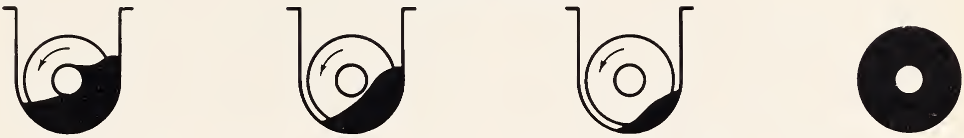


Fig. 37. Square trough for horizontal conveyor, where self-cleaning is not important.

Fig. 38.

LOADING FACTOR



45 per cent loading

Maximum loading, for free flowing grain or finely ground material. For non-abrasive materials, e.g., grain, seeds.

30 per cent loading

Non- or semi-abrasive materials, lumpy or mixed lumpy and fine materials; also for wet and for fluffy materials, e.g., sawdust, wet beet pulp.

15 per cent loading

Abrasive, heavy or stringy materials, e.g., chopped hay, sand.

90 per cent loading

Screw feeder for free-flowing or ground materials, e.g., grain.

CONVEYOR DESIGN

$$\text{Theoretical capacity of full screw (cu. ft. per hr.)} = \frac{(D^2 - d^2)}{36.6} \times P \times \text{rpm}$$

where D = screw diameter in inches
d = shaft diameter in inches
P = screw pitch in inches (normally equal to D)
rpm = revolutions per minute

POWER REQUIREMENT

$$\text{Horsepower} = \frac{CLWF}{33{,}000}$$

where C = conveyor capacity in cu. ft. per minute
L = length of conveyor in feet
W = bulk material weight in lb. per cu. ft.
F = material factor; select from table 4 right

For safety factor

Computed horsepower	*Multiple by*
less than 1	2.0
1 to 2	1.5
2 to 4	1.25
above 5	no correction

Table 4. Material Indices for Screw Conveyors

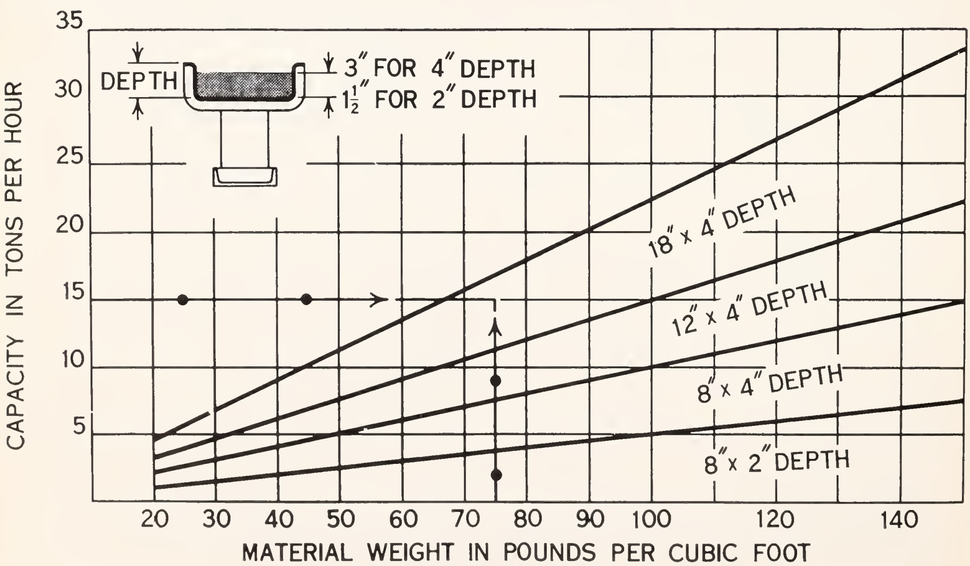
Material	Density (W), lbs. per cu. ft.	Horsepower factor F
Barley	38	0.4
Beans	48	0.4
Soy beans	45–50	0.5
Bran	16	0.4
Corn (shelled)	45	0.4
Cornmeal	40	0.4
Cottonseed (dry)	25	0.9
Cottonseed (hulls)	12	0.9
Lime (ground)	60	0.6
Oats	26	0.4
Rice (clean)	45–48	0.4
Rye	44	0.4
Sawdust	13	0.7
Wheat	48	0.4

Oscillating and vibrating conveyors provide a uniform rate of flow for free-flowing materials on horizontal or near-horizontal runs. Power is applied to a smooth trough through an eccentric or a vibrator designed to impart a forward and upward motion to the trough, thus advancing the material. The trough then falls downward and backward, dropping out from under the material so that it falls to a more forward position on the conveyor. As this cycle is repeated rhythmically, the material advances in a continuous and uniform flow.

Vibrating conveyors are usually low-power, low-capacity units, and are most often used to meter minor ingredients at a constant rate. Vibrating the material has the effect of reducing the angle of repose of the material. Most vibratory feeders operate with the trough sloped about 5 degrees below horizontal, with the vibrator force applied at a right angle to the bottom of the trough. The rate of flow is adjustable by controlling the amplitude of the vibrations, which can be readily controlled on an electric vibrator with a simple rheostat-type voltage controller. Larger changes in rate of flow can be controlled with an adjustable gate that determines the amount of material that can flow into the trough.

Oscillating conveyors, because of the greater amplitude of the eccentric drive, are capable of handling very large capacity with low power requirement. Oscillating conveyors are made in several sizes and types of mounting. The least expensive, which is adequate for most farm operations, is mounted on spring-leaf legs. Heavier-duty units, capable of much greater capacities, are coil-spring- or torsion-bar-mounted. Figures 39 and 42 show the capacities and power require-

Fig. 39. Capacity.



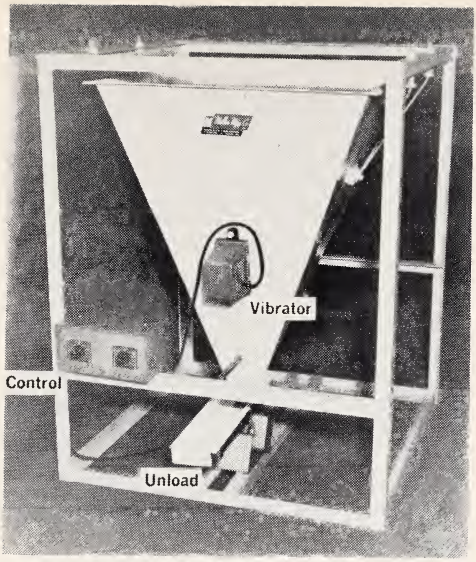


Fig. 40. Vibrator feeder used to meter minor ingredients into grain auger. Rate of flow can be controlled by the turn of a knob.

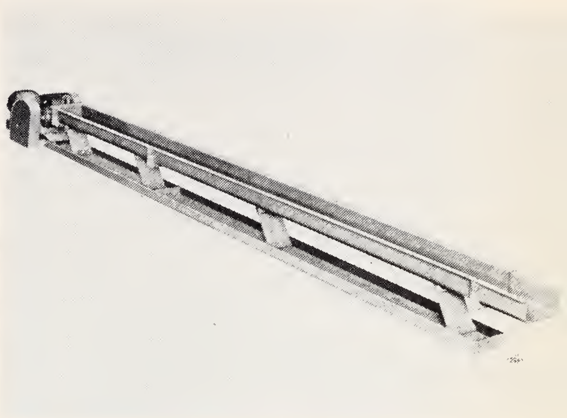
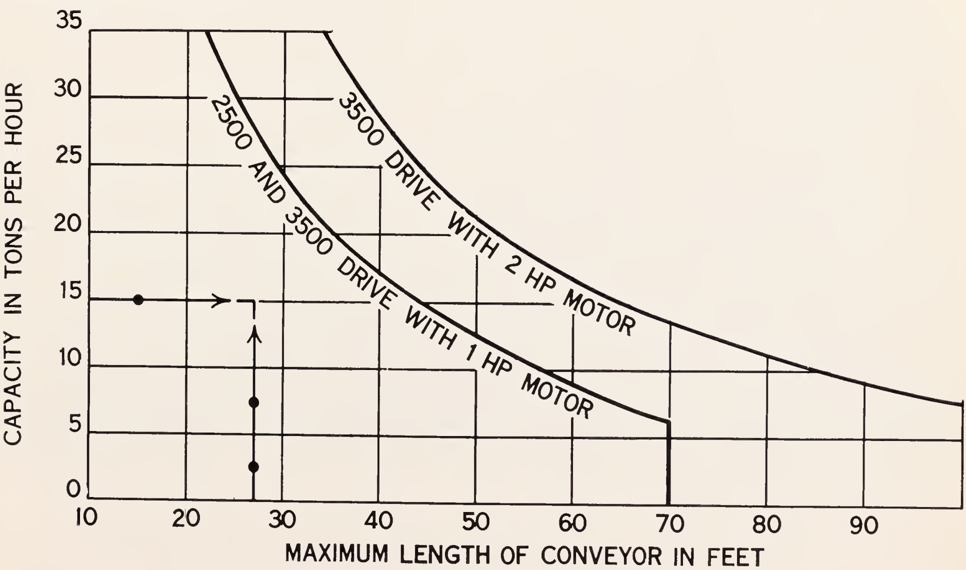


Fig. 41. Spring-leaf-mounted oscillating conveyor

ment for spring-leaf-mounted conveyors of various trough sizes for materials of different weights.

The maximum length of oscillating conveyors is about 100 ft. Oscillating conveyors are expensive, and must be mounted on concrete foundations or specially designed structures. Power requirement is nominal, usually 1 to 2 hp.

Fig. 42. Power Requirement.



GRAVITY CONVEYING

Gravity conveying is accomplished by providing a path for material to fall or slide by its own weight from one location to another. Gravity movement is largely dependent on the flow characteristics of the material. Free-flowing material, such as clean grain, will flow through an opening to the normal angle of repose. With mechanical agitation, a flow pattern can be developed in most ground or granular material, permitting the use of gravity conveying to some lower elevation. The conveying path should be of ample size and slope to permit free movement of the material and should be free of projections or restrictions. Storage bins are designed to utilize gravity flow.

Gravity conveying can also be accomplished in wheeled carts or similar units that will travel a prescribed path by their own weight when loaded. A counterweight may be used to return the cart to its original position after the load has been deposited at the low end of the run. Such a system is most useful where routine deliveries must extend a considerable distance horizontally with limited reduction in height. This type of conveyor is seldom used for handling materials in livestock operations.

Fig. 43. Gravity conveying should be utilized whenever possible. Here a single elevator lifts grain high enough to permit gravity flow to three locations.

The design of a pneumatic conveyor is largely based on experience and judgment. For this reason, a pneumatic system should be designed by a qualified engineer. The data presented here will serve as a guide for simple systems.

TYPES OF PNEUMATIC SYSTEMS

A pneumatic conveyor consists basically of a fan or blower and a duct system, and may be classified as low or high pressure. A low-pressure system is generally limited to pressures below 14 inches of water, which is within the range of a centrifugal fan. A high-pressure system requires a positive-displacement blower or centrifugal compressor. *The material covered here is intended for low-pressure systems.*

Positive - Pressure System. The source of air supply is at the head end of the duct system, and the material is conveyed on the positive pressure side of the positive fan. The material may be introduced on the pressure side of the fan or fed directly into the fan.

Negative - Pressure System. The source of air supply is at the tail end of the duct system, with the material being conveyed on the suction side of the fan.

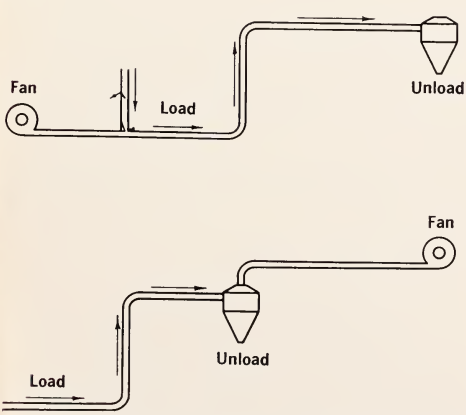


Fig. 44. Top system is positive pressure; bottom system is negative pressure.

As a general rule, use a negative-pressure system for conveying from several points to a single point; a positive-pressure system for conveying from a single point to several points. A negative-pressure system provides cleaner operating conditions where dusty materials are being conveyed.

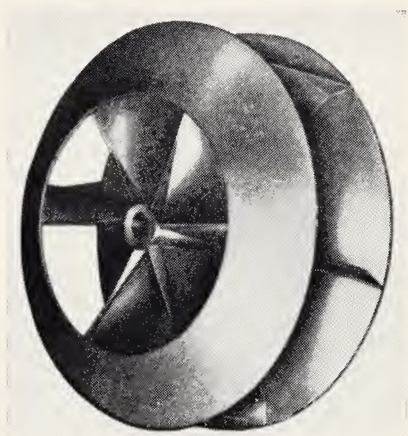


Fig. 45. Side-plate type of fan. Used for handling grain and concentrates.

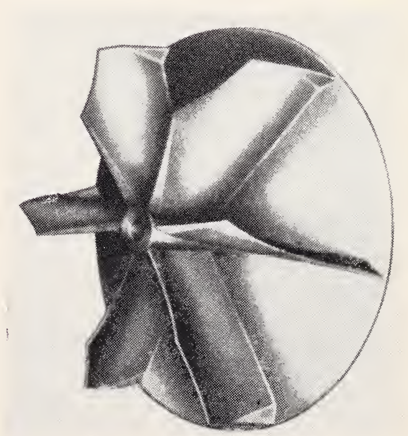


Fig. 46. Open-face type of fan. Used for stringy material such as chopped hay or silage. (Photos courtesy Westinghouse.)

FANS FOR PNEUMATIC CONVEYING

A materials-conveying fan must provide enough pressure to overcome the pressure loss in the system and enough air to carry the material. It should be matched to the system to provide these requirements at maximum efficiency. To do this, the performance curves of the fan and the requirements of the system must be known. In most farm systems, radial-bladed fans (see preceding page) are used since the material passes through the fan. The fan should have an inlet opening at least as large as the conveying pipe.

DESIGN FACTORS

Air Velocity. Table 5 below gives suggested minimum conveying air velocities for materials of different densities. A velocity of 5000 ft. per min. is generally adequate for most farm conveying jobs.

Air Rate. Table 6 below gives suggested air-rate figures. Note that the air rate per lb. of material decreases as the velocity increases. Increasing the operating pressure in a system also decreases the air rate.

TABLE 5. SUGGESTED MINIMUM CONVEYING AIR VELOCITIES (Based on material density)

Material density lbs. per cu. ft.	20	35	50
Minimum conveying velocity, ft. per min.	4000	5000	6000

TABLE 6. SUGGESTED MINIMUM AIR RATES

Material density, lbs. per cu. ft.	Air rate, cu. ft. per min. per lb. material
20	30
35	25
50	20

Pipe Size. Having determined the proper air velocity and rate, pipe size is obtained from the formula $A = \frac{Q}{V}$ where

A = Cross-sectional area of pipe in sq. ft.
Q = Total air rate in cu. ft. per min.
V = Air velocity in ft. per min.

Operating Pressure. This is the total of the following individual losses.

1. *Friction in the duct system (air).* Table 7 (p. 27) shows friction loss in inches of water per hundred feet of smooth pipe.

2. *Friction loss due to elbows or bends (air).* This varies with the size of pipe and radius of the bend. A 90° elbow should have a minimum center-line radius of 3 ft. With such a radius the length of pipe in each elbow may be added to the total length of straight pipe for determining pressure loss.

3. *Entrance loss.* A pressure loss occurs where air enters the system. An entrance will normally add 1½ to 2 inches of water pressure.

4. *Cyclone separators.* Pressure loss varies with the air velocity in relation to the dimensions of the cyclone. See the section on cyclone separators.

5. *Losses due to material in the system*

(a) Acceleration of material. This will vary with the conveying velocity and the amount of air being handled. The pressure loss for acceleration should not exceed 0.5 inch of water pressure for conveying air velocities up to 6000 ft. per min.

(b) Lifting material vertically: use the formula

$$P = \frac{h}{155}, \text{ where}$$

P = inches water pressure
h = vertical lift of material in feet.

(c) Material friction loss. Determine material friction loss in the horizontal duct and elbows. This can be estimated at 0.2 times the friction loss for air only.

Table 7. Friction Loss in Smooth Pipe—Inches of Water per 100 Feet of Pipe

Pipe diameter, inches	Air velocity, feet per minute		
	4000	5000	6000
4	6.9	10.5	...
5	5.0	8.0	...
6	4.0	6.3	8.5
7	3.4	5.2	7.5
8	2.8	4.4	6.3
9	2.5	3.8	5.3
10	2.2	3.4	4.4
12	1.8	2.7	3.8
14	1.5	2.3	3.3
16	1.3	1.8	2.7
18	1.2	1.7	2.4

Fan Horsepower. The size of motor required to operate the fan can be estimated from the static pressure and total air rate by the following formula:

$$\text{HP (approximate)} = \frac{Q \times P}{6330E}, \text{ where}$$

Q = Air rate, cu. ft. per min.
P = Static pressure, inches water
E = Efficiency (will usually vary from 0.4 to 0.7)

Table 8. Equivalent Material Conveying Rates

Lbs. per hr.	1000	2000	3000	4000	5000	6000
Lbs. per min.	17	33	50	67	83	100

Table 9. Volume Weights of Farm Products

Feed	Volume weights	
	lb/cu. ft.	cu. ft./ton
Alfalfa meal	15	134
Alfalfa, baled	10	200
Alfalfa, chopped	12	170
Barley meal	28	72
Barley, whole	38	53
Beet pulp, dried	15	134
Brewers' grains, dried	15	134
Buckwheat bran	15	134
Buckwheat middlings	23	88
Cocoanut meal	38	53
Corn meal	38	53
Corn, whole	46	45
Cotton seed	26	77
Cotton seed meal	38	53
Distillers' grains, dried	15	134
Gluten feed	33	61
Gluten meal	46	45
Hominy meal	28	72
Kaffir meal	27	74
Linseed meal	23	88
Malt sprouts	15	134
Mixed mill feed (bran and middlings)	15	134
Molasses	78	26
Molasses beet pulp	20	100
Oats, whole	26	80
Rice bran	20	100
Rice polish	31	65
Wheat bran	14	154
Wheat feed, mixed	15	134
Wheat, ground	45	46
Wheat middlings (Standard)	20	100
Wheat, whole	48	42
Wheat screenings	27	77
Pellets, mixed feed	35–40	57–50
Pellets, ground hay	38–45	53–44

CYCLONE SEPARATORS

The cyclone separator (usually referred to as a "cyclone") can provide an economical and efficient means of removing material from the air stream of a pneumatic conveying system. It is widely used in the handling of agricultural products such as feeds and seeds.

The separation efficiency of cyclones can be based on (1) percentage by weight of material reclaimed and (2) the degree of atmospheric contamination. These two factors are closely related. In agricultural operations it is important that the separator reclaim a maximum percentage of the material being moved. Material losses can be a significant economic item. Atmospheric contamination may or may not be an important consideration. It is sometimes necessary to reach a compromise between separation efficiency and the cost of the job.

CYCLONE CLASSIFICATION

Cyclone separators are generally classified as of large or small diameter. The large-diameter cyclone handles most agricultural jobs of feed and seed separation satisfactorily. The large-diameter classification refers to a cyclone with a body diameter 3½ to 6 times the diameter of the inlet pipe. Large-diameter cyclones can be used to separate particles as small as 50 microns. Small-diameter cyclones with long cones are used for more difficult separation jobs involving smaller particles.

PRINCIPLES OF OPERATION

The cyclone separates particles from the air by centrifugal force and gravity. Air and material enter tangentially at the top and descend in a helical pattern with the material being thrown to the outside. The air then moves upward to the outlet in a smaller inner helix or vortex. Fig. 47 shows the air movement in a typical cyclone. The force of separation is proportional to the square of the particle velocity, directly proportional to the length of cone, and inversely proportional to the radius of the cone. This means that best separation results from a high inlet velocity and a long small-diameter cone. Increasing inlet velocity and decreasing diameter also increases pressure drop in the cyclone, so it is sometimes necessary to reach a compromise between pressure drop and separating efficiency.

For most agricultural applications there seems to be considerable tolerance in the design of cyclone separators. Even so, there are some guide posts to follow in selecting or building a cyclone. They are:

Size. The size depends primarily on the volume of air, and hence the amount of material it is required to handle. Table 10 gives suggested dimensions for large-diameter cyclones based on total air rate.

Pressure Drop. As has been mentioned, the pressure drop through a cyclone varies with a number of factors, including air velocity, diameter, design, installation, etc. Some manufacturers provide pressure-drop data for their cyclones. If the manufacturer has not provided the information needed, the following rule-of-thumb method, based on air velocity at the inlet to the cyclone, may be used for estimating pressure drop through a well proportioned large-diameter cyclone.

Inlet Air Velocity *Ft. per min.*	Static Pressure *Inches water*
Up to 2800	1½
2800–3200	2
3200–4000	3½

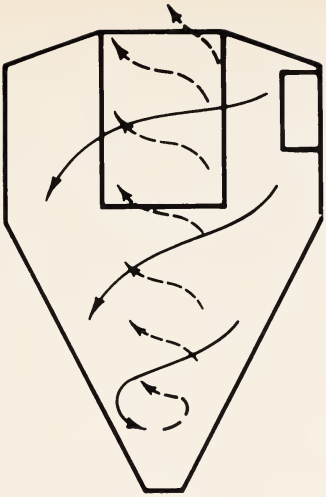


Fig. 47. Schematic diagram of air flow through a cyclone separator. Solid lines indicate the descending vortex, from which solid particles are separated. Broken lines show the inner vortex of "clean" air.

Such refinements as an inlet deflector and a helical top can be used to minimize pressure drop but are generally not used unless pressure drop is critical. An inverted cone or flat disc is sometimes installed below the inner cylinder as a means of improving performance. The inner cylinder (fig. 48) may be built as a telescoping sleeve for critical adjustment of its length.

Proper installation and operation are important for best cyclone performance:

1. The material discharge outlet should be sufficiently sealed to prevent excessive air movement through it. Air movement through the material outlet disrupts the circulation pattern in the cyclone.

2. If a centrifugal fan is mounted on the air outlet of the cyclone, the direction the fan turns should be the same as that of the air in the cyclone.

3. Avoid elbows in the piping system closer than 20 pipe diameters to the cyclone inlet.

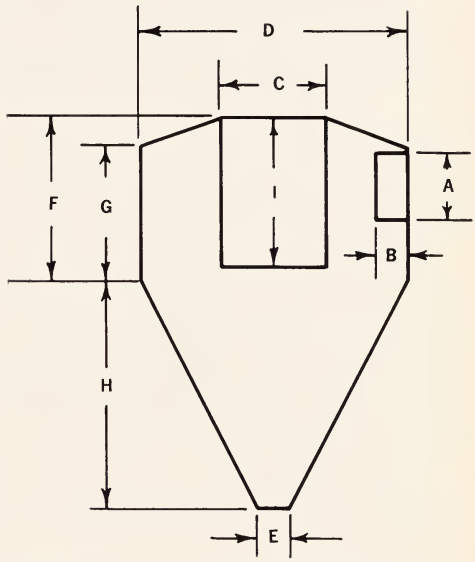


Fig. 48. Dimension diagram for large-diameter cyclone.

Table 10. Suggested Dimensions for Large-Diameter Cyclones*

Air rate CFM	A	B	C	D	E	F	G	H	I
300	7½″	2″	8″	2′-0″	2″	16″	12″	2′-6″	See footnote
500	9½″	2½″	10″	2′-4″	3″	18″	14″	2′-10″	
600	10″	3″	12″	2′-6″	4″	20″	15″	3′-0″	
800	11″	3½″	14″	3′-0″	6″	23″	18″	3′-10″	
1200	13″	4½″	16″	3′-6″	6″	2′-3″	21″	4′-4″	
1600	13″	6″	18″	3′-10″	6″	2′-5″	23″	4′-8″	
1900	15″	6″	20″	4′-2″	10″	2′-11″	2′-4″	5′-0″	
2600	17″	7½″	2′-0″	4′-8″	10″	3′-0″	2′-4″	5′-2″	
3300	19″	8½″	2′-4″	5′-4″	10″	3′-5″	2′-8″	5′-4″	
4500	2′-0″	9″	2′-8″	6′-0″	12″	3′-9″	2′-11″	6′-0″	
5700	2′-6″	9″	3′-0″	6′-8″	12″	4′-3″	3′-4″	6′-8″	
6700	2′-9″	10″	3′-4″	7′-4″	12″	4′-8″	3′-8″	7′-4″	

* Refer to corresponding letters in fig. 48.
I Make inner cylinder telescoping for adjustable length.

COMMON METHODS OF FEEDING MOLASSES

1. Mixed with ground feeds—this is the most common method.

2. Self-fed directly from a barrel placed on end, or from a shallow pan; or metered from a container with a float valve.

3. Poured or sprayed directly on the feed.

STORAGE OF MOLASSES

Molasses may be stored indefinitely in steel or concrete tanks.

Steel tanks are usually black iron, of welded construction, with the inside coated to prevent rust from condensation. The tank should be vented.

Concrete tanks should be of monolithic construction, tightly tamped, made in a single pouring. The inside surface should be plastered smooth, then sealed with an odor-free and tasteless coating, such as sodium silicate, plastic, or special silo sealer. Tanks should:

1. be moisture tight,

2. be vented above the molasses to prevent condensation,

3. have a top opening to permit gauging and cleaning,

4. be strong enough to withstand the pressure (greater than water), and

5. have a bottom slope of 6 in. per 10 ft. to permit gravity flow.

PUMPING MOLASSES

Screw, plunger, or rotary pumps may be used; variable-flow rotary pumps are most common. Rotary pumps should be operated at low speed, less than ½ the speed recommended for water.

$$\text{Capacity of pump for molasses} = \frac{\text{rpm with molasses} \times \text{capacity with water}}{\text{rpm with water}}$$

Pumps. A 1½-inch gear pump, operating at 100 rpm and 75 psi (pounds per square inch) discharge pressure, will deliver 8 gal. per min: Use a 1-hp. motor (add ½ hp. for each additional 50 rpm).

A 2-inch gear pump, at 100 rpm and 75 psi, will deliver 17 gpm and requires a 1½-hp. motor (add ¾ hp. for each additional 50 rpm).

A spring-loaded relief valve, set for maximum design pressure (usually 75 psi) should be on discharge side of pump. Hand-operated valve permits bypassing back to tank or suction side, preventing excessive delivery of molasses.

Locate pump near bottom outlet of tank. Pump can "push" easier than it can "pull."

Inspect pump regularly. No special maintenance required.

Uniform viscosity is important in maintaining a uniform delivery rate.

PIPING SYSTEM

Small pipes are the main source of trouble in pumping molasses. Suction line to pump should be twice the pump inlet size. Black iron pipes are used except that galvanized pipe may be used to reduce exterior rusting. Avoid sharp bends. Slope lines to provide necessary drainage. Provide a pressure gauge for the operator. Pipe sizes may be selected from table at bottom of page 31.

HEATING MOLASSES

Molasses can be readily mixed at 70° F; there is no advantage in a higher temperature. It should not be heated above 110° F and may caramelize if in contact with surfaces above 250° F.

Immersion coils or jacketed pipe. May be heated with water or steam. Keep steam pressure below 5 lbs. to avoid excessive temperature.

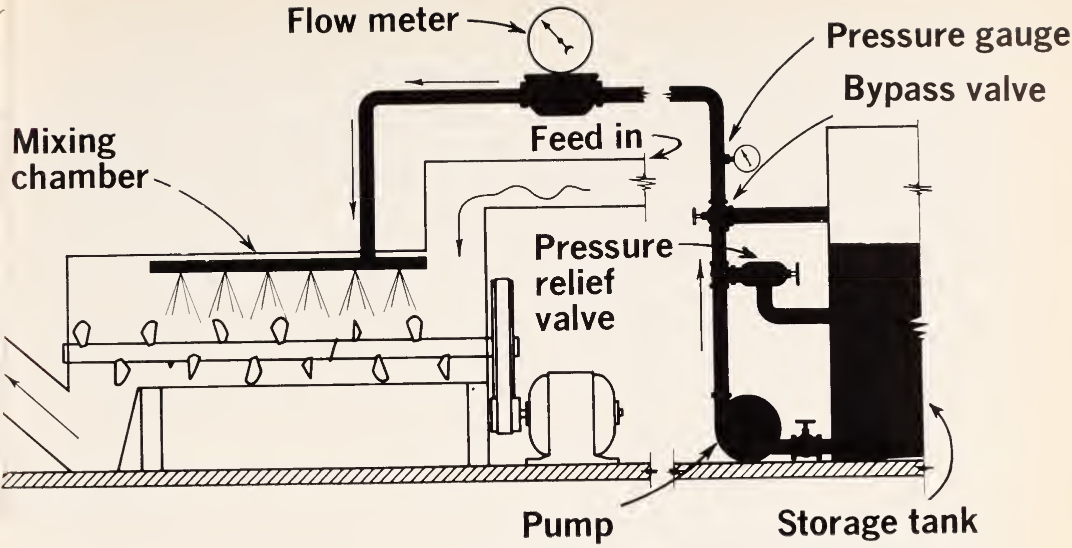


Fig. 49. System for mixing molasses with feed.

Electric heaters. Immersion heaters should be thermostatically controlled, and heater should be immersed at all times to prevent burning. Soil-heating cable may be wrapped on exposed pipes. Pipe and cable should be enclosed with insulation, and a thermostat should be used. A 60-ft. 400-watt cable wrapped around a 2½-foot length of 2″ pipe will raise molasses temperature 2° F at a flow rate of 2 gallons per minute.

MIXING MOLASSES WITH FEED

The system varies with the method of mixing feed. Where the grinder is used as the mixer molasses must be added in a separate mixing operation, usually a high-speed paddle-type mixer. This is also the preferred method for batch mixing systems, unless the batch mixer is designed to handle molasses without causing balling of the feed. For pelleted feed, the molasses may be added in the pellet-

RECOMMENDED SIZE OF PIPES FOR PUMPING MOLASSES AT 50° F.*

Length of pipe	Gallons per minute pumped			
	0 to 2	2 to 5	5 to 10	10 to 20
feet	*Suction pipe dia. in inches*			
0 to 4	2	2½	3	4
4 to 8	2½	3	4	5
8 to 20	3	4	5	6
	Discharge pipe dia. in inches			
0 to 5	1¼	1½	2	2½
5 to 10	1½	2	2½	3
10 to 25	2	2½	3	4
25 to 50	2½	3	4	5

* Based on maximum vacuum of 20 in. mercury and maximum pressure of 75 pounds per sq. in. For 70°F, decrease cross-sectional area of pipe by ⅓; for 100°F, by ½.

mill mixer. A flow meter can be used to measure the amount of molasses applied. The rate of flow can be adjusted to the flow of dry feed into the mixer.

PHYSICAL PROPERTIES OF MOLASSES

Moisture content: about 22 per cent, wet basis.

Weight: at 68° F, 11.75 lb. per gallon or 170.3 gallons per ton.

Viscosity: varies greatly with temperature. An increase of 10 to 15° F approximately halves viscosity of molasses.

PHOSPHORIC ACID WITH MOLASSES*

Phosphoric acid may be added to molasses as a source of phosphorous and as a means of lowering the viscosity. The addition of 3 per cent phosphoric acid by weight will reduce the viscosity of molasses by 13.9 per cent. Phosphoric acid weights 13.1 pounds per gallon.

* Courtesy Maus Division, Stauffer Chem. Co., and Pacific Molasses Co.

SELECTION OF DRIVE

TYPE OF DRIVE

Direct-connected flexible coupling—
Shaft speed of motor and machine are the same.

V-Belt drive—
Most versatile; can be used for most installations.

Chain drive—
For low-speed positive drive.

Speed-reducer drive—
Good, but more expensive. Used where speed of machine differs greatly from motor speed.

Flat belt—
For long-distance drives.

V-BELT DRIVES

V-belt drives are convenient, give trouble-free service, and are simple to figure and easy to install. To plan a V-belt drive determine:

1. Speed of the driver or motor.

2. Speed at which machine is to be driven.

3. Size of pulley on the motor.

(a) If speed of machine is less than that of the driver, select this pulley according to minimum standards shown in the first table below.

(b) If speed of machine is more than that of the driver, select driver pulley large enough to provide adequate-sized driven pulley.

To determine size of pulleys, use this formula:

$D \times RPM = d \times rpm$, where

D = diameter of driver pulley in inches

RPM = speed of driver shaft in revolutions per minute

d = diameter of driven pulley in inches

rpm = speed of driven shaft in revolutions per minute.

Selection of Belts. Belts are available in cross-section sizes designated as A, B, C, D, and E. A, B, and C belts will handle most farm loads, the C section belts being used mainly for 10 hp. or greater loads. The second table below gives the hp. ratings of these belts operating on different size pulleys at 1725 rpm. Determine the load one belt will handle, then divide this into the load to be handled to determine the number of belts needed. Where two or more belts are needed, use matched belts.

Minimum-Sized Pulleys for 1725-RPM Motors

Motor hp	1/6	1/4	1/3	1/2	3/4	1	1 1/2	2	3	5	7 1/2
Motor pulley diam. in inches	2.25	2.5	2.75	3.0	3.5	4.0	4.0	4.5	5.0	5.5	5.5

Approximate Horsepower per Belt for 1725-RPM Motors

Motor pulley diam. in inches	2.25	2.5	2.75	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0
Hp./belt—A section	0.5	0.6	0.7	0.8	1.2	1.4	1.8	2.0	..	..	..	..	..
Hp./belt—B section	..	..	..	..	..	..	2.0	2.4	3.0	3.4	4.0	4.3	..
Hp./belt—C section	..	..	..	..	..	..	..	..	..	..	..	4.8	6.2

How to Determine Length of Belt

Length of belt $= 1.6\ (D_1 + D_2) + 2C$

where D_1 = pitch diameter of driver pulley, in inches

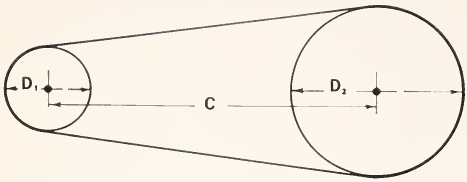


Fig. 50.

D_2 = pitch diameter of driven pulley, in inches

C = distance between centers of pulleys, in inches

This will give the pitch length of the belt.

Tips for Good Installation

1. Use clean belts and pulleys. Clean off grease and dirt.

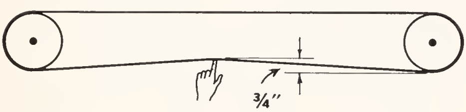


Fig. 51.

2. Do not use bent or badly worn pulleys.

3. Release the take-up adjustment before removing or replacing belts.

4. Check pulley alignment by placing a straight edge against the sides of the pulleys.

5. Proper belt tension is important for power transmission and for long belt life. Allow ½″ to ¾″ depression for each foot of distance between pulley centers (see fig. 51.

6. Keep shaft center distance as short as practical.

7. Use matched belts for multiple drives.

8. Top of V-belt should be about flush with the outside of the pulley. If belt becomes worn so that it rides in the bottom of the groove, it should be replaced (see fig. 52.

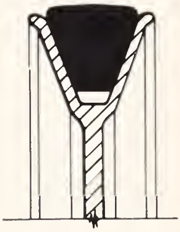


Fig. 52.

EXAMPLES OF CALCULATIONS

THE PROBLEM

To move 10 tons per hour of ground grain weighing 30 lbs. per cu. ft. a distance of 150 feet horizontally and 25 feet vertically. No obstructions.

SOLUTION

There are several possible methods of handling this problem, including:

(a) An inclined chain and flight conveyor.
(b) An inclined belt conveyor.
(c) A horizontal belt or chain conveyor and a bucket elevator.
(d) An inclined screw conveyor, or
(e) A pneumatic conveyor.

The following calculations, using the information in this circular, show several possible solutions to the problem.

Inclined chain and flight conveyor

Assume flight speed of 100 feet per minute.

Capacity = 1.15 × area of cross section × 100

$$\frac{20{,}000}{30 \times 60} = 1.15 \times \text{area} \times 100$$

area = 14 sq. inches

Use a conveyor 6 inches wide with flights $2\frac{1}{2}$ inches high. This will provide ample capacity at this incline.

Pull on chains = L (WF + 2 wf)

For a conveyor 6 in. wide, use single chain with $2\frac{1}{2}'' \times 6''$ crossflights about 12 inches apart.

For #55 chain—detachable link

Weight per foot = 0.6 lb.

one $2\frac{1}{2}'' \times 6''$ flight = 0.4 lb. (estimated)

w = 1.0 lb.

f = metal on wood (table 3, p. 19)—0.55

F = grain on board (table 2, p. 19)—0.35 (smooth board)

$$W = 30 \times \frac{6}{12} \times \frac{2.5}{12} = 3.12$$

L = 150 + 2.5 × 25 = 212.5 ft.

Pull = L (WF + 2 wf) = 212.5 (3.12 × 0.35 + 2 × 1.0 × 0.55) = 465.4 lbs.

This is more than the safe working load for #55 cast chain. Use #55 pressed steel. #62 cast chain weighs more. Pull = 558.9 pounds.

$$\text{Power required} = \frac{1.4 \times \text{conveyor speed} \times \text{pull on chain}}{33{,}000}$$

$$= \frac{1.4 \times 100 \times 465.4}{33{,}000} = 1.97 \text{ hp for \#55 pressed steel chain.}$$

Use a 2 hp motor (for #62 cast chain, hp = 2.37)

Inclined Belt Conveyor

Because of the slight incline, a sliding belt operating in a wood trough can be used. The power requirement is figured below for both a sliding belt and a troughed belt with anti-friction rollers.

For 12″ flat sliding belt

Capacity at 100 fpm $= \frac{30}{50} \times 5.7 = 3.4$ tons per hr. (See table on p. 15.)

Belt speed required for 10 tons per hr. $= \frac{10 \times 100}{3.4} = 294$ fpm. Use 300 fpm.

Horsepower required:

1. For empty conveyor $= \frac{S(.015W + .001WL)}{100}$

$$= \frac{300(.015 \times 12 + .001 \times 12 \times 152)}{100} = 5.94$$

2. To convey material horizontally $= \frac{\text{capacity } (0.48 + 0.0302L)}{100}$

$$= \frac{10(0.48 + .0302 \times 152)}{100} = 0.507$$

3. To lift material $= \frac{\text{lift} \times 1.015 \times \text{capacity}}{1000}$

$$= \frac{25 \times 1.015 \times 10}{1000} = 0.254$$

Total hp. for sliding belt $= 5.94 + 0.507 + 0.254 = 6.701$ hp. Use a $7\frac{1}{2}$ hp. electric motor.

For troughed belt

Capacity at 100 fpm $= \frac{30 \times 11.5}{50} = 6.9$ tons per hr.

Belt speed required for 10 tons per hr. $= \frac{10 \times 100}{6.9} = 145$ fpm. Use 150 fpm.

Horsepower required:

1. For empty conveyor $= \frac{S(.015W + .0001WL)}{100}$

$$= \frac{150(.015 \times 12 + .0001 \times 12 \times 152)}{100} = 0.54$$

2. To convey material horizontally $= \frac{\text{capacity } (0.48 + 0.00302L)}{100}$

$$= \frac{10(0.48 + 0.00302 \times 152)}{100} = 0.094$$

3. To lift material $= \frac{\text{lift} \times 1.015 \times \text{capacity}}{1000}$

$$= \frac{25 \times 1.015 \times 10}{1000} = 0.254$$

Total hp. for troughed belt $= 0.54 + 0.094 + 0.254 = 0.888$ hp. Use a 1-hp. electric motor.

Bucket Elevator

A bucket elevator may be used with any of the horizontal conveyors to lift the material.

$$\text{Hp.} = \frac{QH}{33{,}000} = \frac{\frac{20{,}000 \times 25}{60}}{33{,}000} = .25 \text{ hp.}$$ Use a ¼- or ⅓-hp. electric motor.

FROM THE TABLE ON PAGE 16: To handle 10 tons per hour of 30 lb./cu. ft. material requires a 7″ × 4½″ bucket spaced 15″ on center, operating at a belt speed of at least 300. Recommended head pulley size: 24″, turning 50 rpm.

Screw Conveyor

A screw conveyor can be used horizontally in combination with a vertical screw or bucket elevator, or as an inclined conveyor. At this degree of incline, hp. requirement would vary little from horizontal conveyor.

$$\text{Hp.} = \frac{C\,L\,W\,F}{33{,}000} = \frac{11.1 \times 150 \times 30 \times 0.4}{33{,}000} = 0.61$$

where $C = \frac{20{,}000}{60 \times 30} = 11.1$ cu. ft. per min.

For safety factor hp. = 2 × 0.61 = 1.22.

Use a 1½-hp. electric motor.

Size of screw required:

Capacity in cu. ft. per hr. $= \frac{20{,}000}{30} = 667$ cu. ft./hr.

FROM TABLE ON PAGE 20:

At 30% loading, use a 12-inch screw.

At 45% loading, use a 9-inch screw.

Because of length of conveyor, 45% loading is maximum.

Pneumatic Conveyor

Assume a negative-pressure layout as shown in figure 53.

AIR RATE. From table 6 (page 26), select air rate of 25 cfm per lb. per min. (20,000 lb./hr = 333 lb./min) 333 × 25 = 8,000 cfm.

AIR VELOCITY. From table 5, select air velocity of 5,000 fpm.

PIPE SIZE. $A = \frac{Q}{V} = \frac{8{,}000}{5{,}000} = 1.6$ sq. ft. = 17″ diam.

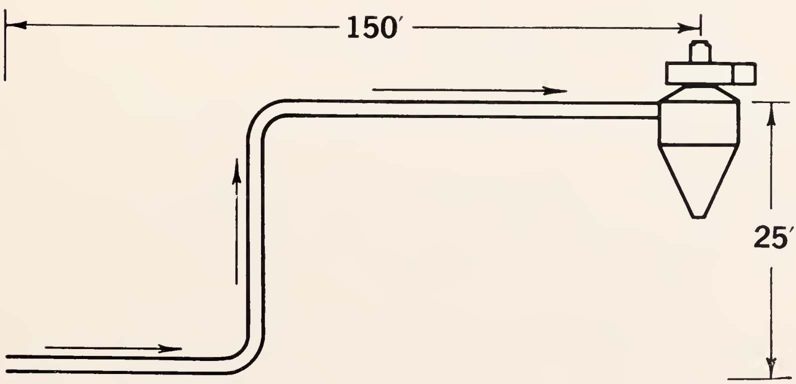


Fig. 53.

Operating pressure

a) Pipe friction loss for air.

Total equivalent pipe length $= 150' + 25' + 15'^* = 190$ ft.

*Equivalent length of straight pipe for two 90° elbows (3′ radius)

From table 7, friction loss for air at 5,000 fpm in a 17″ pipe = 1.75 in. water per 100 ft.

$$\text{Total friction loss} = 1.75 \times \frac{190}{100} = 3.3 \text{ in. water}$$

b) Entrance loss; use 1.5 in. water.

c) Presure loss for material in system:

For acceleration—0.5 in. water

$$\text{For vertical lift} \; - \; \frac{h}{155} = \frac{25}{155} = 0.2 \text{ in. water}$$

$$\text{Friction in horizontal pipe} = 0.2 \times \text{loss for air} = 0.2 \times 1.75 \times \frac{150}{100} = 0.5 \text{ in. water}$$

d) Cyclone separator—2.0 in. water

(Assume large-diameter cyclone with entrance velocity less than 3,000 ft. per min.)

Total presure loss for system = 8.0 in. water

Estimated horsepower

$$\text{Hp} = \frac{Q \times P}{6330\ E} = \frac{8000 \times 8.0}{6330 \times 0.5} = 20 \text{ hp.}$$

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BLACK BOXES...

Agriculture has them too

Both manned and unmanned vehicles sent into space are equipped with "black boxes" that record or transmit information needed by space scientists who hope to explore other planets.

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